JULY 27, 2018 | OLD SAYBROOK, CT

ISO Presentation

Review of 2018 Early Summer Weather & Load

Discussion of Electrification/Decarbonization

Proposed Energy Modeling Changes

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Objectives

1. Discuss weather and preliminary loads so far this summer
2. Begin a discussion of emerging forecasting issues related to beneficial electrification/decarbonization in the region
3. Share and discuss scenario estimates of the potential impacts of electric vehicle growth on regional energy and demand and the relative uncertainty
4. Discuss proposal for monthly energy forecast modeling

REVIEW OF EARLY SUMMER 2018 WEATHER AND LOAD

2018 Summer Weather & Preliminary Net Load

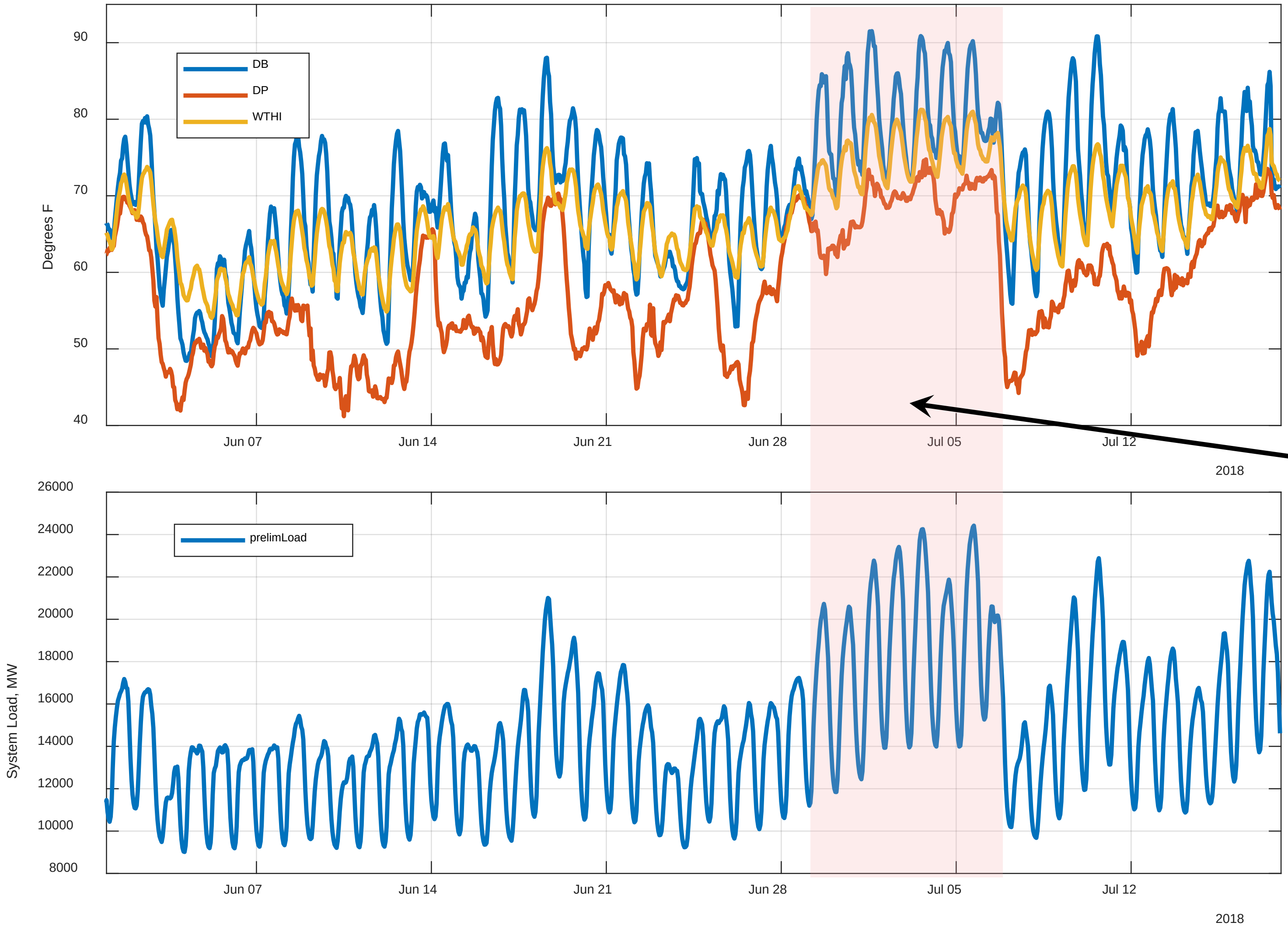
- The next two slides contain plots illustrating the weather and preliminary net loads experienced in New England so far this summer
- The plots on slide 5 show the period June 1, 2018 to July 18, 2018
  - Hourly regional dry bulb (DB) and dew point (DP) temperatures, 3-day weighted temperature-humidity index (WTHI), and preliminary net load
- The plots on slide 6 focus on the week of June 30, 2018 to July 7, 2018, which included July4th, which fell on a Wednesday
  - Shows hourly WTHI for each of ISO's eight weather stations and regional weighted, and preliminary net load

$$WTHI_h = \frac{10 * THI_h + 5 * THI_{h-24} + 2 * THI_{h-48}}{17}$$

$$THI_h = 0.5 * DryBulbTemp_h + 0.3 * DewPointTemp_h + 15$$

Regional Summer Weather & Preliminary Net Load

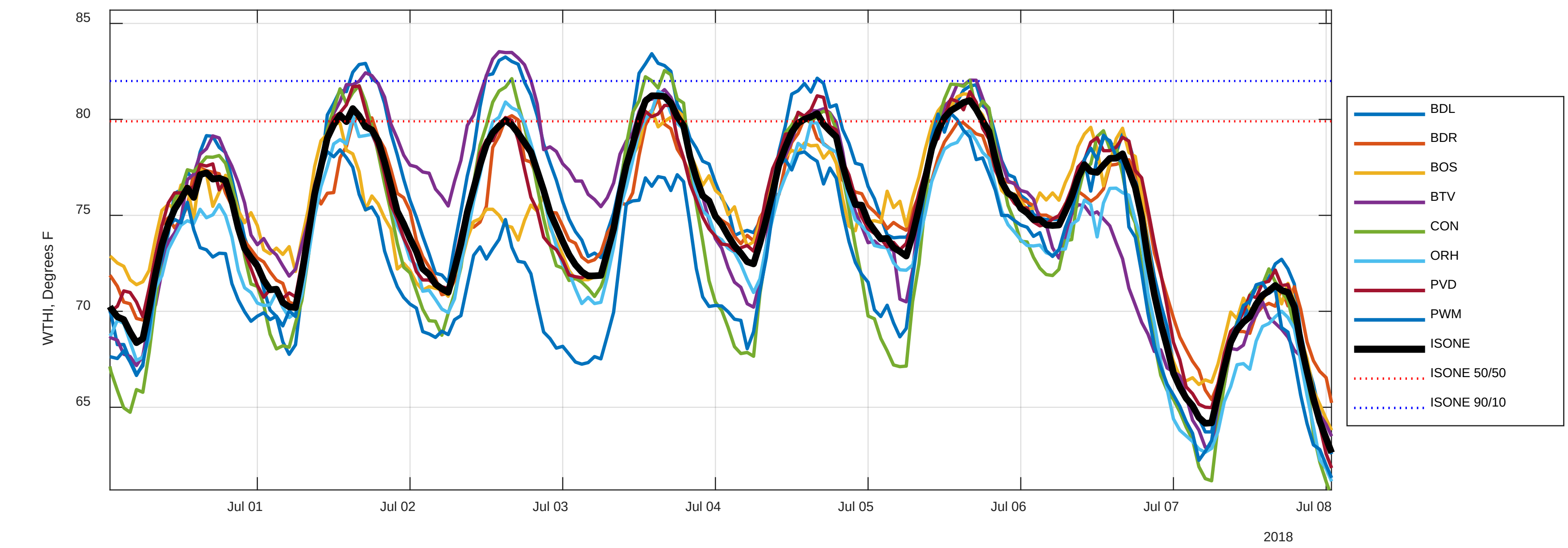
8-City Weighted Weather, June 1-July18, 2018

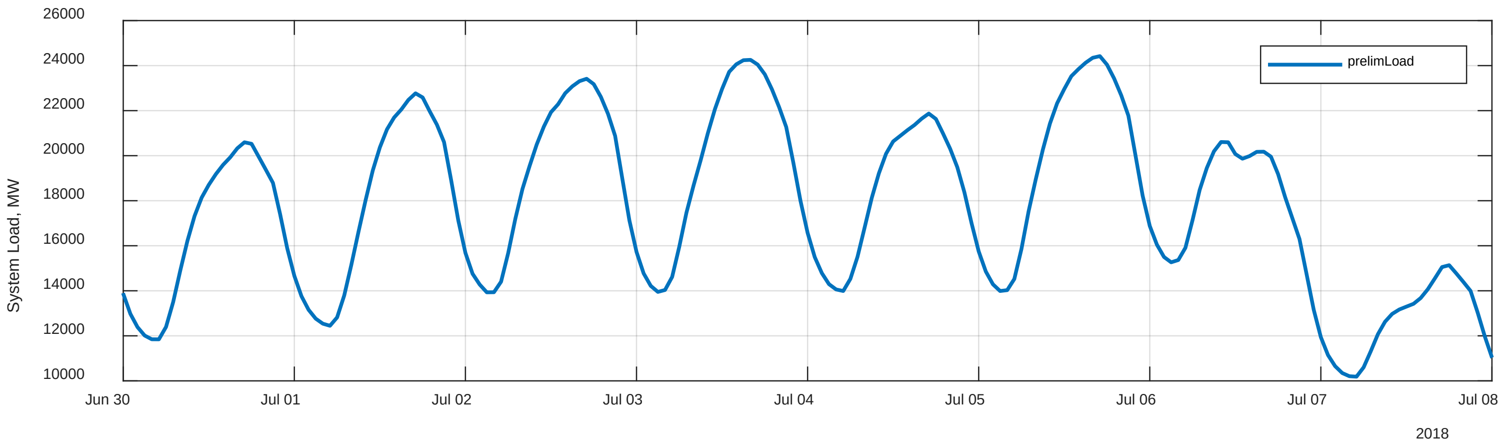


Further detail on this period shown on next slide

Regional WTHI and Preliminary Net Load

June 30, 2018-July 7, 2018





Observations

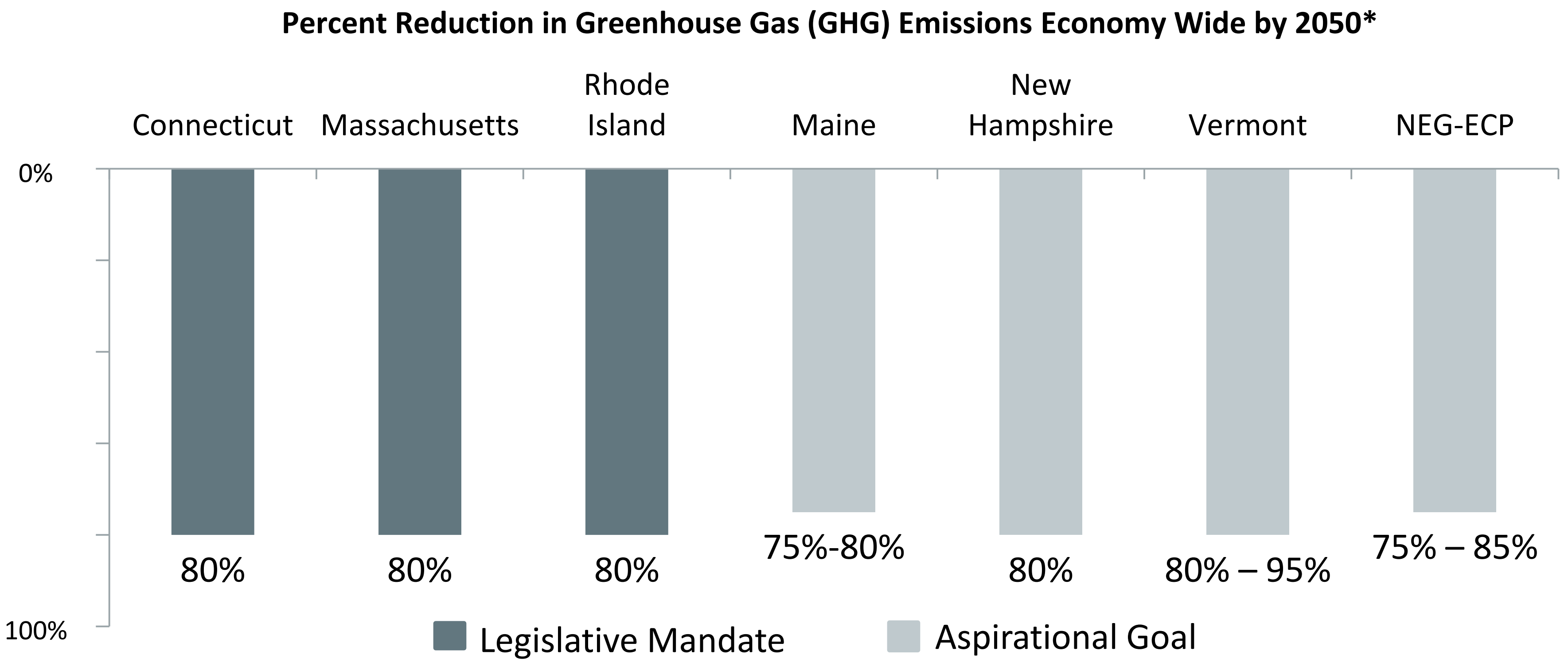
- From July 1st (Sunday) to July 5th (Thursday), the region experienced an extended heat wave of 5 consecutive days with WTHI as high or greater than the 50/50 (WTHI = 79.9) during afternoon hours
  - The exact timing, duration, and degree of extreme weather varied across the load centers in the region
- Preliminary summer peak net load of approximately 24,425 MW occurred on July 5th, the day after the holiday
  - This value will change as part of the wholesale energy market's data reconciliation process (DRP)
- The heat wave coincided with the July 4th holiday week, with the holiday occurring on a Wednesday
  - Consequently, the reducing effects of the holiday on electricity demand were present to varying degrees for the entire week

EMERGING FORECASTING ISSUES

Introduction

- Early signs of "strategic" or "beneficial" electrification are beginning to emerge in New England
  - Includes electric vehicles and air-source heat pumps (ASHPs)
- Achieving long-term greenhouse gas (GHG) reduction goals across the region via electrification would introduce demand for a significant amount of electric energy to the regional grid that is not currently sourced in the electricity sector

States Have Set Goals for Reductions in Greenhouse Gas Emissions: *Some Mandated, Some Aspirational*

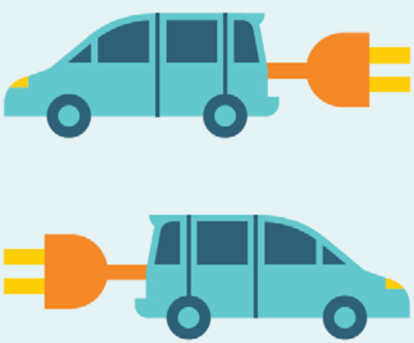


The New England states are promoting GHG reductions on a state-by-state basis, and at the regional level, through a combination of legislative mandates (e.g., CT, MA, RI) and aspirational, non-binding goals (e.g., ME, NH, VT and the New England Governors and Eastern Canadian Premiers).

* MA, RI, NH, and VT use a 1990 baseline year for emissions reductions. CT and the NEG-ECP use a 2001 baseline. ME specifies reductions below 2003 levels that *may* be required "in the long term." For more information, see the following ISO Newswire article: http://isonewswire.com/updates/2017/3/1/the-new-england-states-have-an-ongoing-framework-for-reducin.html.

2018 Regional Electricity Outlook

- The 2018 load forecast indicates that net demand will trend downward over the next decade
- Regional efforts to meet economy-wide decarbonization goals will likely reverse this trend, especially over the longer term



Decarbonization of Transportation and Heating Could Impact the Grid

A possible future trend that the ISO is watching out for is the increased adoption of electric vehicles (EVs) across the region and the greater use of electric heating. Both could increase in the future as part of the New England states' efforts to achieve their decarbonization goals. Vehicle manufacturers are also moving aggressively to include EVs in their product portfolios by the early 2020s. If rapid EV or electric heating adoption emerges, the impacts may need to be considered in the ISO's outlook for the region's demand and energy. The ISO plans to start working with regional stakeholders to quantify the impact of the states' decarbonization policies on long-term demand so that we can understand their potential effects on the power system and reflect these in future Regional System Plans.

Source: 2018 Regional Electricity Outlook

Regional Trends Changing Electricity Consumption Patterns

Yesterday, Today, and Tomorrow

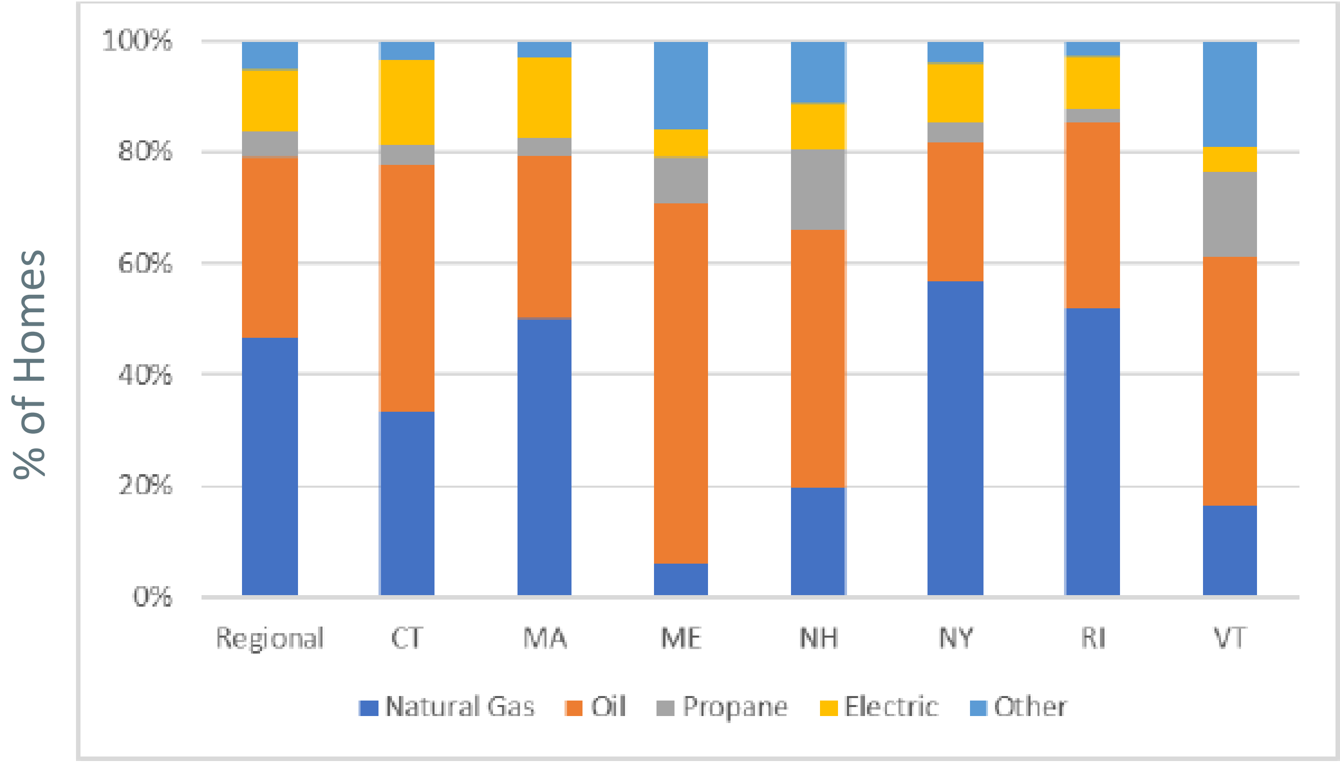
- Historical and Future
  - Energy efficiency (includes market-based and "codes & standards")
  - Behind-the-meter photovoltaics
- Future
  - Electrification of transportation sector
    - E.g., electric vehicles
  - Electrification of heating sector
    - E.g., Air-source heat pumps (ASHP), a.k.a. cold-climate heat pumps
- ISO is actively working to better understand the overall landscape and anticipated outlook for emerging electric end uses, and their potential impacts on energy and demand
- ISO will discuss with the LFC any proposed updates or changes to forecast methodology as appropriate

Some State Policies Promoting Electric Vehicles

- Connecticut
  - CT Hydrogen and Electric Automobile Purchase Rebate (CHEAPR)
- Massachusetts
  - MA electric vehicle incentive program (MassEVIP)
  - Department Of Energy Resources' MA Offers Rebates for Electric Vehicles (MOR-EV) Program
  - Goal of 300k ZEVs by 2025
- Rhode Island
  - Driving RI to Vehicle Electrification (DRIVE) – program suspended on July 10, 2017
- Vermont
  - Drive Electric VT
  - VT EV Charging Station Program

Primary Heating Fuels in Northeastern States

One- to Four-Family Homes



Source: American Community Survey 2015, 5-year estimates

New England Air-Sourced Heat Pump Installations

State	Years Reported	Approximate Number of Units Installed
Maine	2011-FY2016	25,000 (Residential and Commercial)
Connecticut	2012-2015	6176
Massachusetts	2015-2016	9000
New Hampshire	2018 2019 2020	1230 1408 1923
Rhode Island	2018-2020	3000 (mini-split) 90 (central) 75 (oil switches)
Vermont	2014-2018	8200

Source: Vermont Energy Investment Corporation, *Driving the Heat Pump Market: Lessons Learned from the Northeast*, February 20, 2018

SIZING UP POTENTIAL ELECTRIC VEHICLE (EV) GROWTH AND RELATED IMPACTS ON DEMAND AND ENERGY

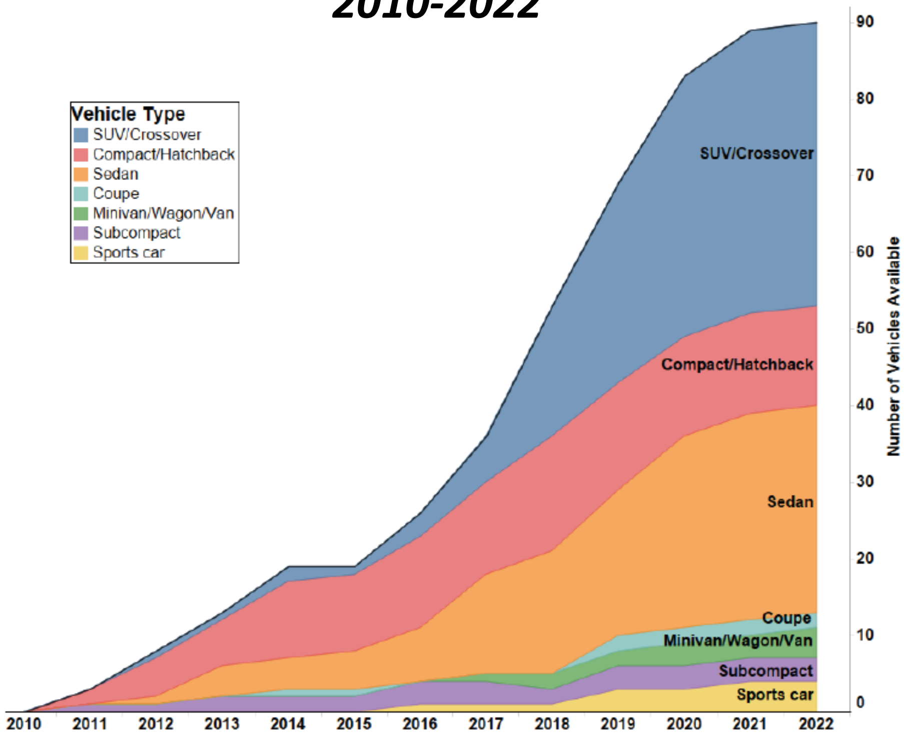
Introduction

- The ISO is currently investigating the regional outlook for electric vehicle (EV) growth and considering its potential impacts on the long-term load forecast
- The ISO has yet to develop formal projections of EV growth, but has used EIA's projections to develop scenarios to preliminarily estimate potential EV growth and its impact on annual energy and peak demand
  - The more aggressive scenario is roughly indicative of EV growth needed to meet goals outlined in the eight-state zero-emission vehicle (ZEV) Task Force's memorandum of understanding (MOU)
- EV projections included herein are for discussion purposes only

The EV Market is Evolving

- An increasing number of automakers are offering more EV choices, and this trend is projected to continue
  - Including significant growth in SUV/Crossover vehicle class
- The nationwide charging network is expanding, enabling more consumers to consider EVs
- Battery technology is advancing and reducing EV costs

Number and Variety of Electric Vehicles 2010-2022



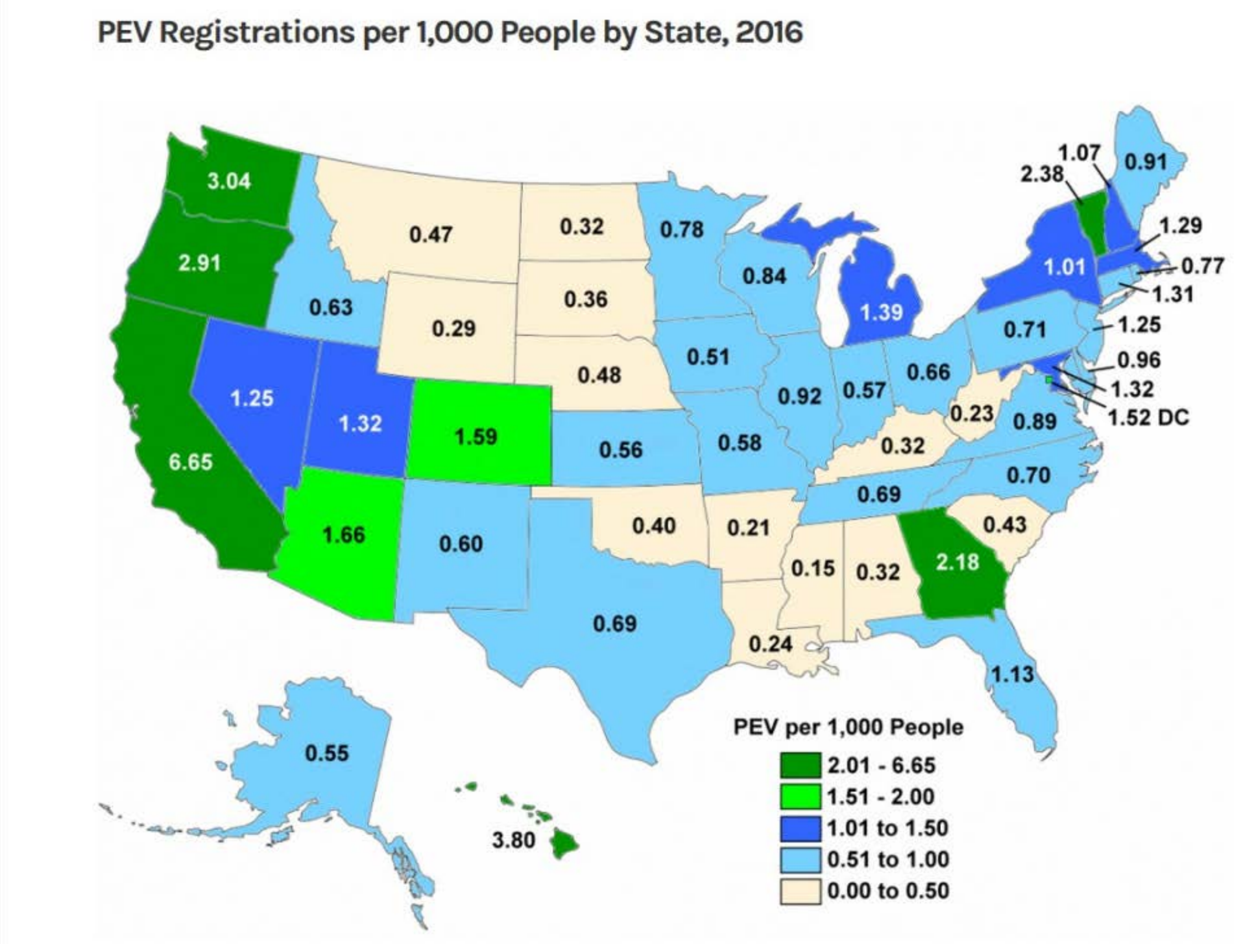
Source: Electric Power Research Institute, A U.S. Consumer's Guide to Electric Vehicles, February 2018.

Electric Vehicles

Factors Influencing EV Energy and/or Demand Impacts

- Historical EV penetration and geographical distribution
  - EV registration data
- Future EV growth and geographical distribution
  - EV costs, gasoline prices, federal and state policy, etc.
- Composition of EVs and their respective ranges
  - Plug-in hybrid electric vehicles (PHEVs)
  - Battery electric vehicles (BEVs or PEVs)
  - Electric bus, rail, and trolley
- Charging technology and use patterns
  - Level 1, Level 2, Fast Charging
- Charging coincidence factors (CF) and their influences
  - Charging time series data to make data-driven assumptions
  - Influences include TOU rates, etc.

Penetration of Electric Vehicles by State



Source: U.S. Department of Energy
www.energy.gov/eere/vehicles/articles/fotw-1004-november-20-2017-california-had-highest-concentration-plug-vehicles

Electric Vehicle Stock

As of December 31, 2017

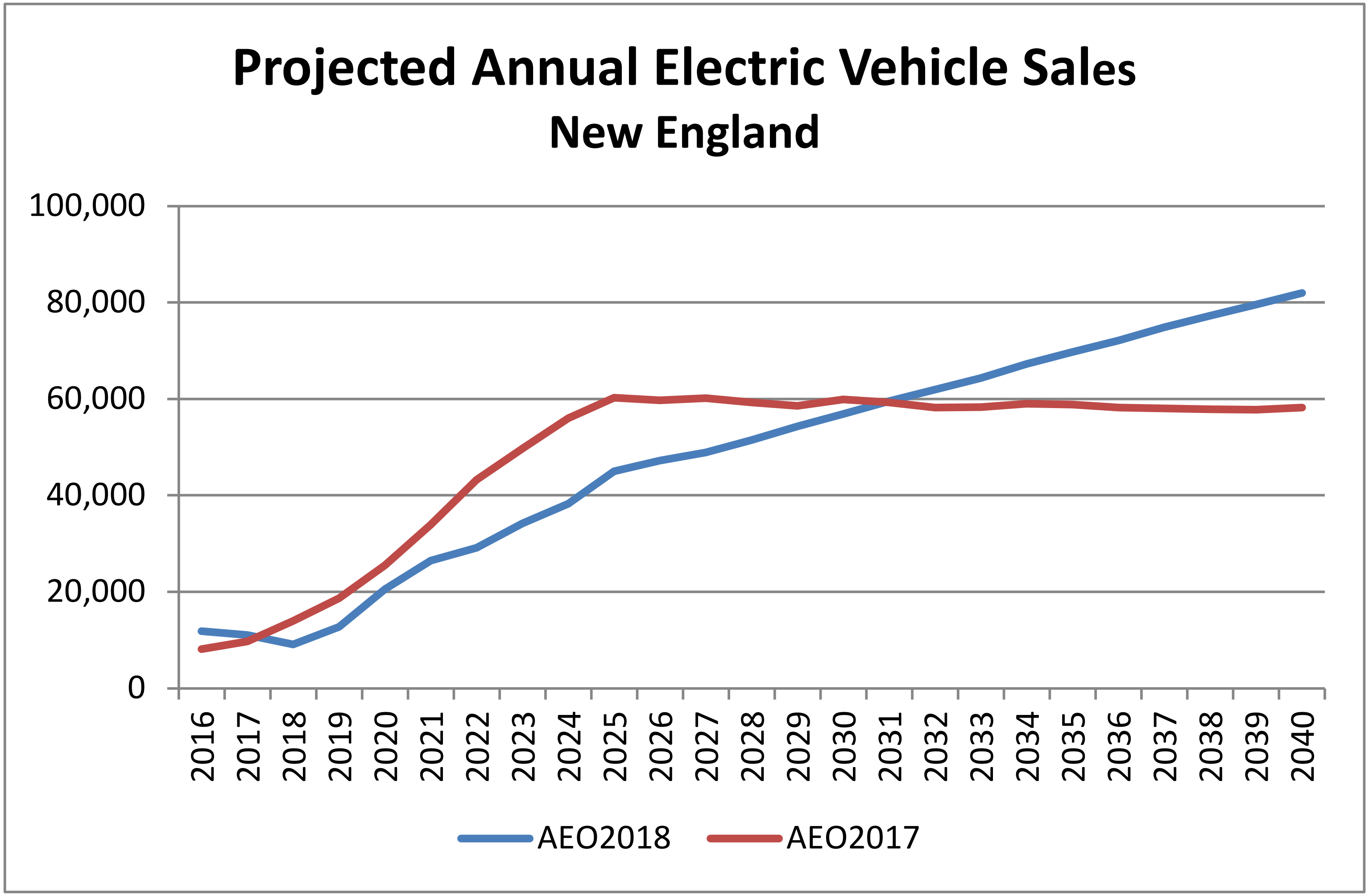
	2017 Population * (1,000s)	Electric Vehicles #	Plug-In Hybrid #	Total	EV Registrations per 1,000 people
Connecticut	3,588	2,909	3,962	6,871	1.91
Maine	1,336	415	1,278	1,693	1.27
Massachusetts	6,860	5,898	8,003	13,901	2.03
New Hampshire	1,343	636	1,515	2,151	1.60
Rhode Island	1,060	362	835	1,197	1.13
Vermont	624	684	1,581	2,265	3.63
New England	14,810	10,904	17,174	28,078	1.90

Notes:

1. * Population estimate as of Jul 1, 2017, Source: U.S. Census Bureau, https://www.census.gov/data/datasets/2017/demo/popest/state-total.html
2. Data source for vehicle registrations: https://autoalliance.org/in-your-state/

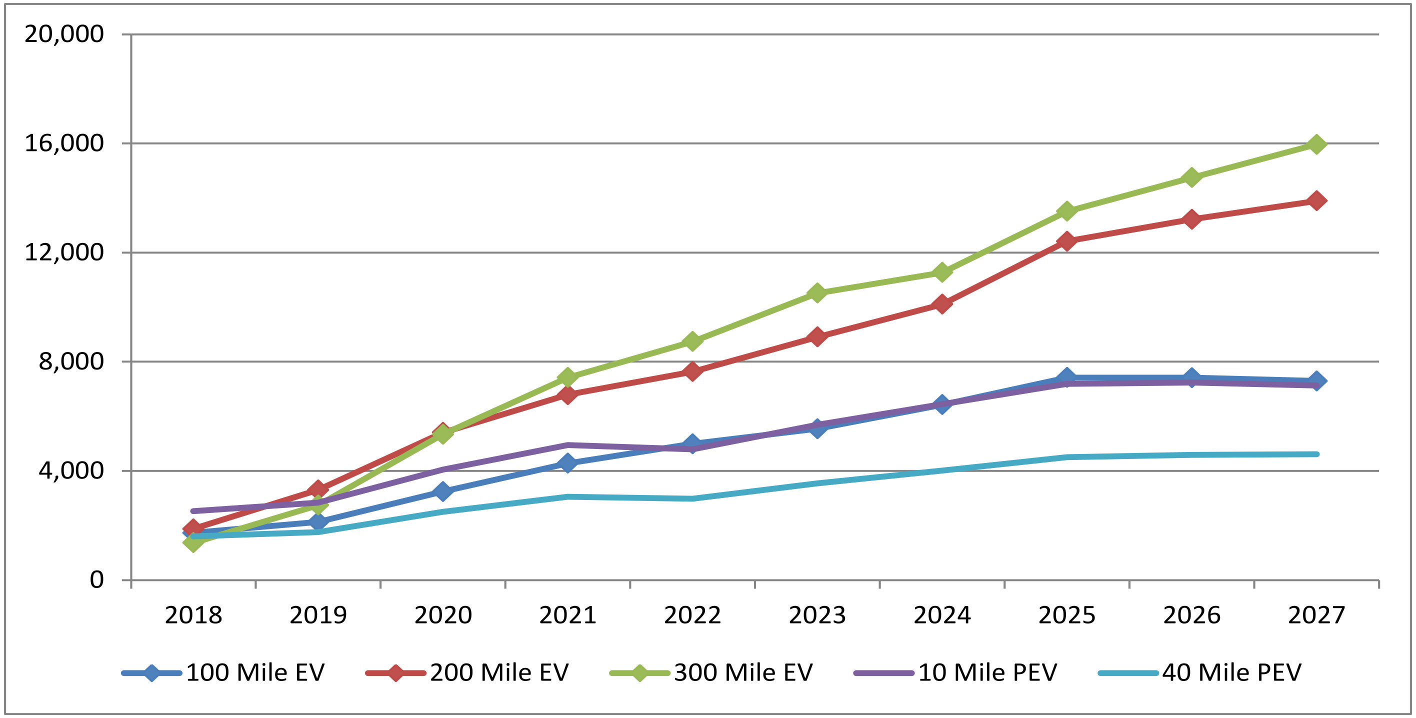
EIA EV Growth Projections

AEO2018 vs. AEO2017



AEO2018 Projection of EV Sales by Type

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
100 Mile Electric Vehicle	1,731	2,127	3,243	4,277	4,993	5,542	6,422	7,419	7,413	7,293
200 Mile Electric Vehicle	1,875	3,301	5,403	6,788	7,633	8,908	10,108	12,415	13,216	13,894
300 Mile Electric Vehicle	1,364	2,743	5,336	7,420	8,737	10,511	11,267	13,513	14,744	15,965
Plug-in 10 Gasoline Hybrid	2,523	2,832	4,043	4,950	4,795	5,694	6,440	7,187	7,233	7,124
Plug-in 40 Gasoline Hybrid	1,602	1,758	2,496	3,055	2,983	3,540	4,015	4,497	4,588	4,615
Total	9,095	12,761	20,522	26,490	29,141	34,194	38,251	45,030	47,194	48,891



NREL Simulated Electric Vehicle Charging Profiles

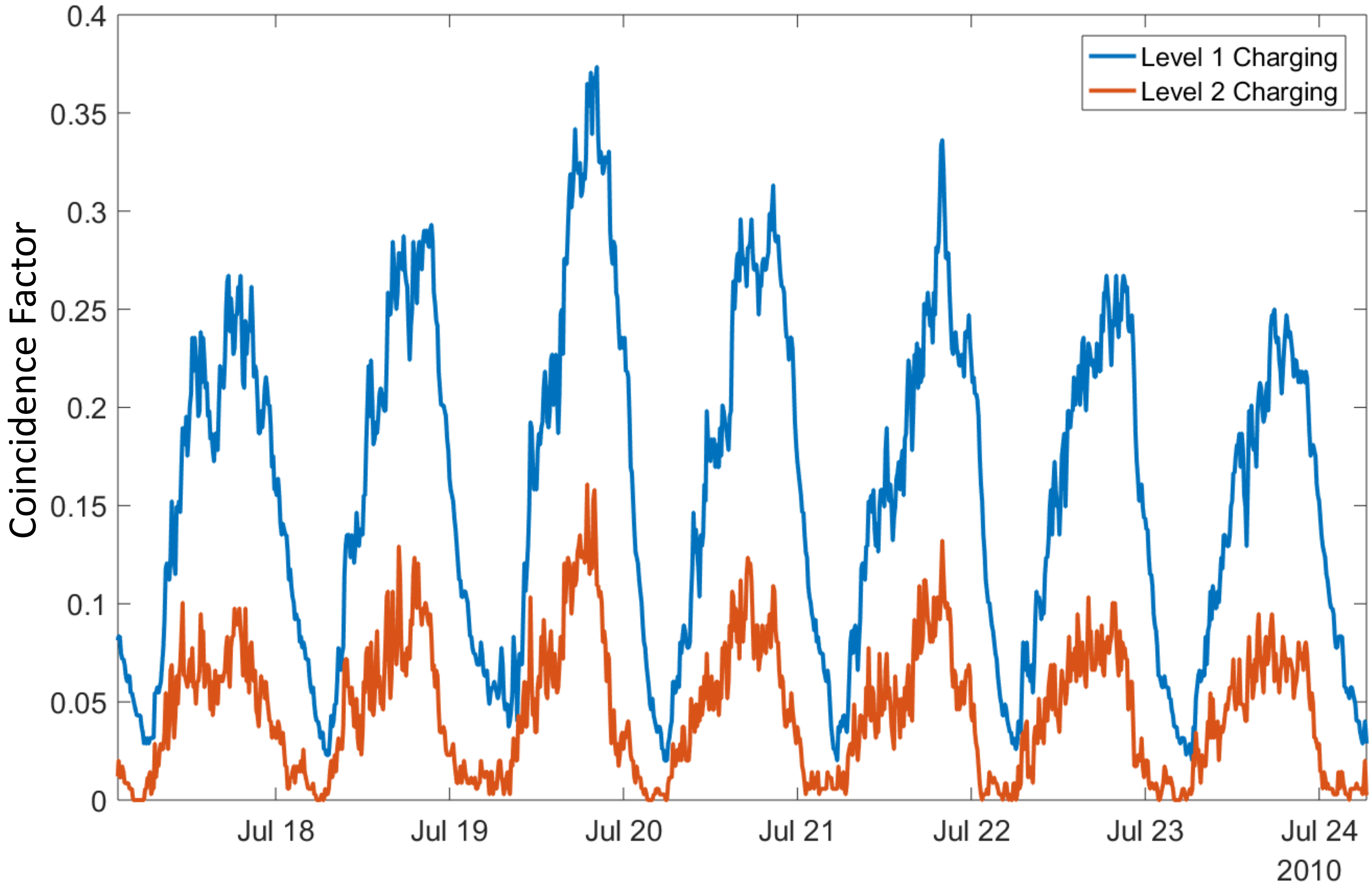
Charging Coincidence Factors

- Based on load profiles of 200 households in the Midwest from 2009
- Simulated fleet of 348 vehicles
  - 1 year of data (2010)
  - 10 minute resolution
  - Level 1 charging (1.92 kW)
  - Level 2 charging (6.6 kW)
- The plots on the following three slides are based on the aggregated charging coincidence factors for all cars in the simulated fleet

Data Source: Muratori, Matteo (2017): Impact of uncoordinated plug-in electric vehicle charging on residential power demand - supplementary data. National Renewable Energy Laboratory. https://dx.doi.org/10.7799/1363870

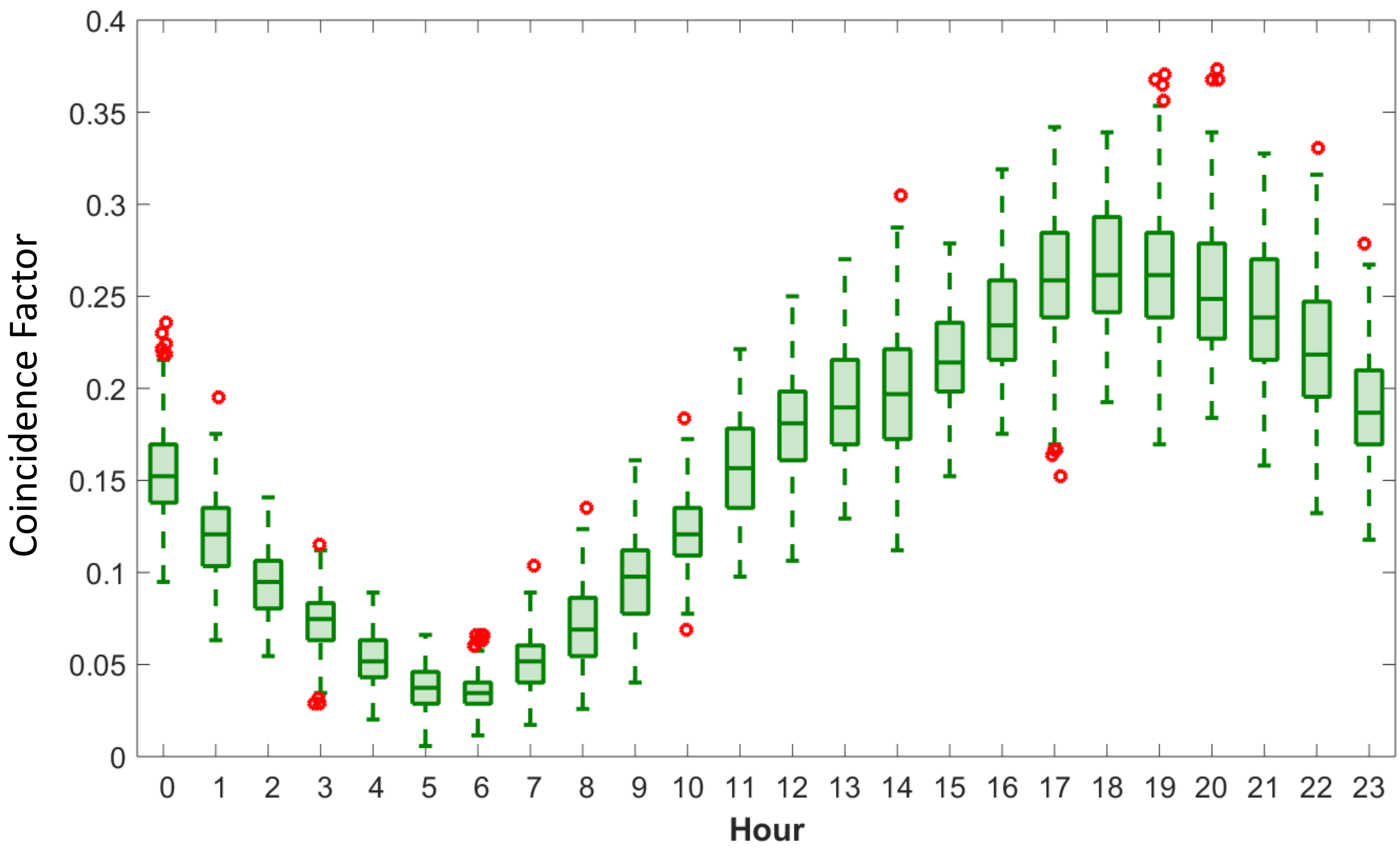
NREL Simulated Profiles

10-Minute Level 1 and Level 2 Charging Profiles



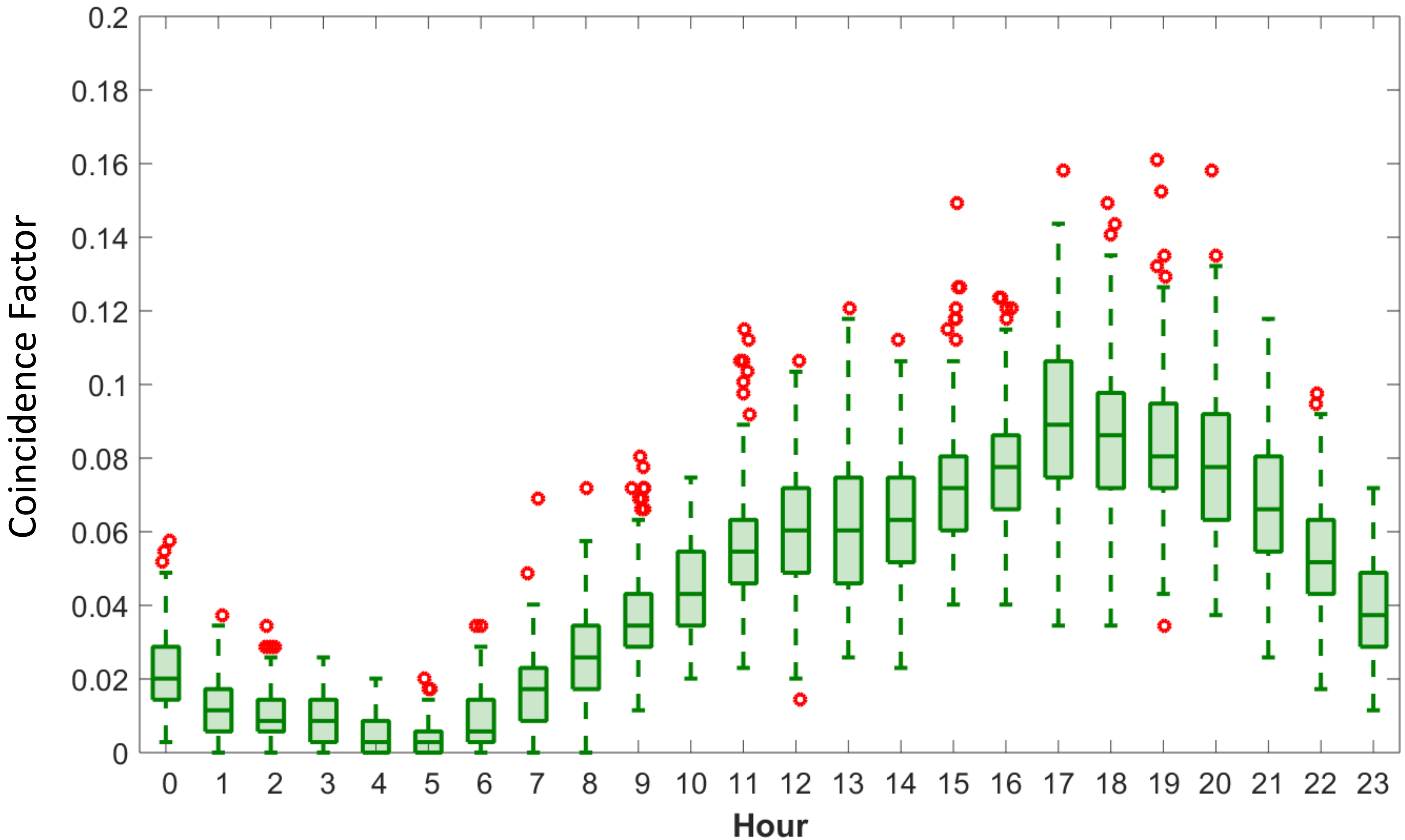
NREL Simulated Profiles

Hourly Boxplot of Level 1 Charging Coincidence Factors – July



NREL Simulated Profiles

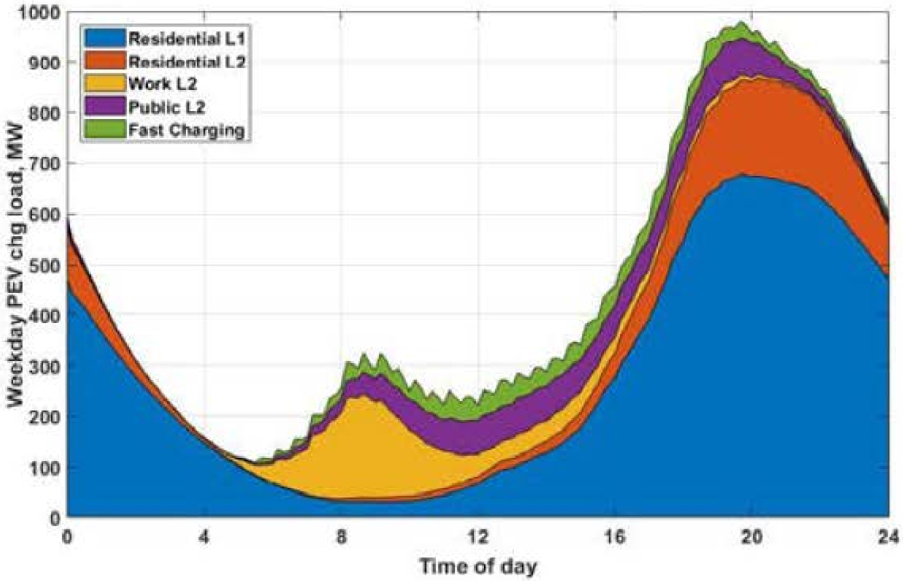
Hourly Boxplot of Level 2 Charging Coincidence Factors – July

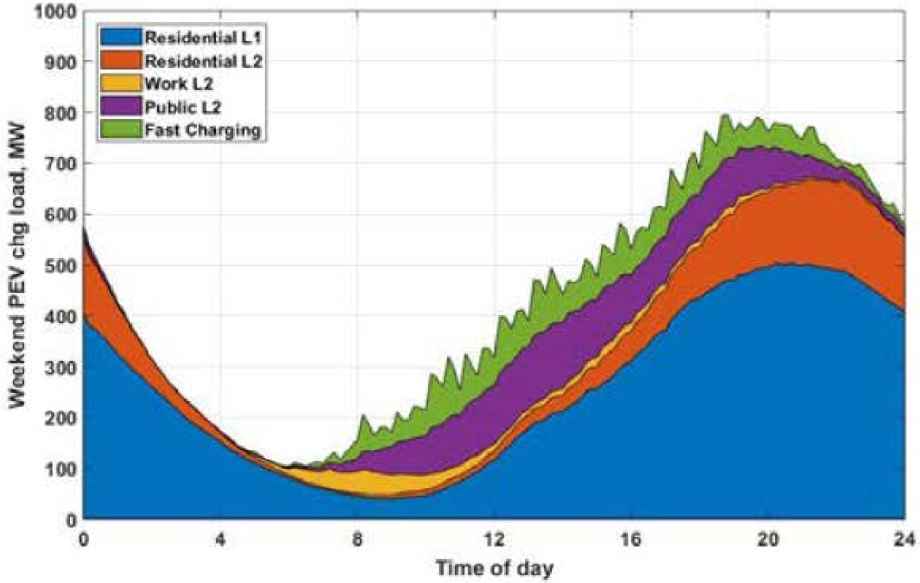


California Energy Commission Study

CA Plug-in EV Infrastructure Projections: 2017-2025

- CA has a goal of 1.5 million ZEVs by 2025
  - At the end of 2017, 350k electric vehicles were on the road in CA
- NREL modeled behavior of PEV drivers to predict charging infrastructure needs to meet state goals
  - Modeling resulted in the weekday (left) and weekend (right) charging profiles for 2025 shown below (a.k.a., the "Dragon Curve")





Source: Bedir, Abdulkadir, Noel Crisostomo, Jennifer Allen, Eric Wood, and Clément Rames. 2018. *California Plug-In Electric Vehicle Infrastructure Projections: 2017-2025*. California Energy Commission. Publication Number: CEC-600-2018-001.

Electric Vehicle Scenarios and Assumptions

- BEV and PHEV sales from EIA 2018 AEO projections for New England (2 scenarios)
  - 1 x EIA Sales
  - 2 x EIA Sales (double growth)
- 2 Charger Types (Level 1 and Level 2)
  - Level 1 charger draws 1.4 kW
  - Level 2 charger can draw 6 kW, typical battery acceptance rate = 3.3 kW
  - (Did not include fast-charging)
- Base assumptions:
  1. 90% households on Level 1 charger, 10% on Level 2 charger
  2. Automobile mileage 12,000 to 13,000 miles per year
  3. Miles per KWh=3.0 (ITRON)
  4. Charger use coincident factors of 100%,50% and 30% simulated
  5. 50% of new fleet turnover after 8 years
  6. All vehicles are all-electric (no PHEVs)

Scenario Calculations

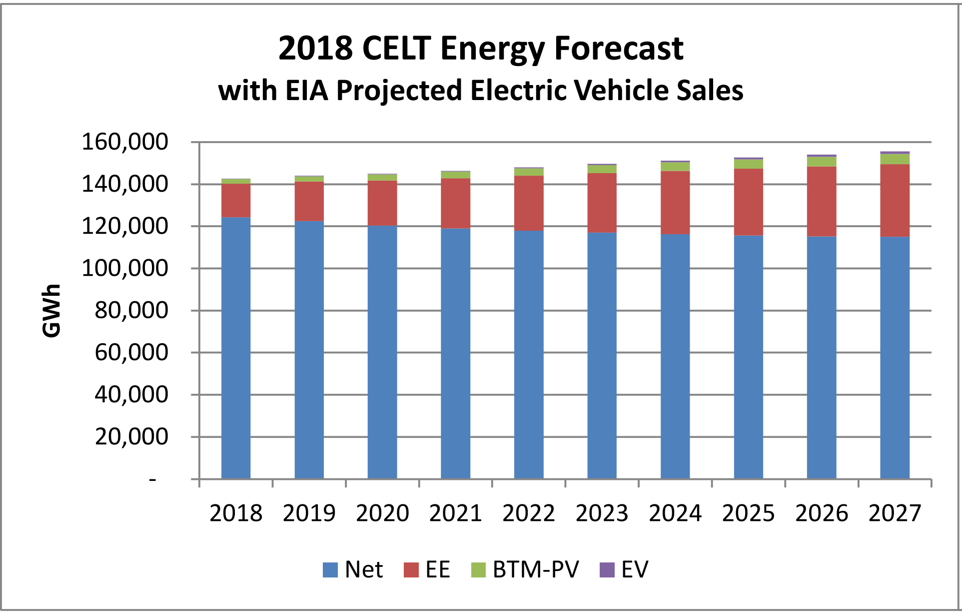
						Begin miles 12,000				Charger Ratio			
						End miles 13,000				0.90	0.10		
										Hour Method			
Year	Total Vehicle Sales (thousands)	EV Sales (cars, light trucks)	EV Decay	EV Stock	EV Share of Total Sales	Average Annual Miles	Miles/KWh	UEC (KWh)	Energy (GWh)	Level 1 Charge (MW)	Level 2 Charge (MW)	Demand at 100% CF	Demand at 50% CF
2016	775.5	11,875	0	17,080	1.5%	12,000	3.0	4,000	68	18.7	4.7	23.4	11.7
2017	743.9	10,998	0	28,078	1.5%	12,080	3.0	4,027	113	31.0	7.7	38.7	19.4
2018	765.9	9,095	0	37,173	1.2%	12,161	3.0	4,054	151	41.3	10.3	51.6	25.8
2019	763.8	12,761	0	49,934	1.7%	12,243	3.0	4,081	204	55.8	14.0	69.8	34.9
2020	759.5	20,522	0	70,456	2.7%	12,324	3.0	4,108	289	79.3	19.8	99.1	49.6
2021	741.1	26,490	1,781	95,165	3.6%	12,407	3.0	4,136	394	107.8	27.0	134.8	67.4
2022	741.9	29,141	3,668	120,637	3.9%	12,490	3.0	4,163	502	137.6	34.4	172.0	86.0
2023	748.6	34,194	5,253	149,578	4.6%	12,574	3.0	4,191	627	171.8	42.9	214.7	107.3
2024	750.8	38,251	7,147	180,683	5.1%	12,658	3.0	4,219	762	208.9	52.2	261.1	130.5
2025	754.8	45,030	9,960	215,753	6.0%	12,742	3.0	4,247	916	251.1	62.8	313.8	156.9
2026	761.7	47,194	12,397	250,550	6.2%	12,828	3.0	4,276	1,071	293.5	73.4	366.9	183.4
2027	765.0	48,891	15,452	283,989	6.4%	12,914	3.0	4,305	1,222	334.9	83.7	418.6	209.3
2028	770.9	51,509	19,321	316,177	6.7%	13,000	3.0	4,333	1,370	375.4	93.8	469.2	234.6

Estimated EV Energy with Projected EIA Sales

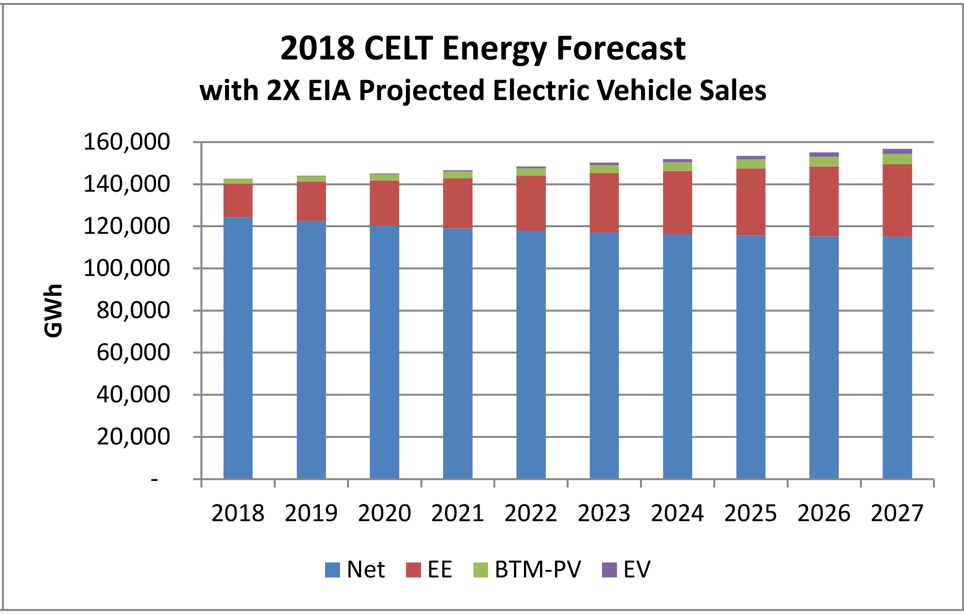
	2018 CELT (GWh)				
	Net	EE	BTM-PV	EV	% of Net
2018	124,252	16,074	2,162	151	0.12%
2019	122,498	18,764	2,558	204	0.17%
2020	120,395	21,332	2,906	289	0.24%
2021	118,949	23,827	3,233	394	0.33%
2022	117,870	26,128	3,540	502	0.43%
2023	117,039	28,228	3,834	627	0.54%
2024	116,249	30,121	4,115	762	0.66%
2025	115,594	31,811	4,361	916	0.79%
2026	115,196	33,302	4,575	1,071	0.93%
2027	114,981	34,601	4,783	1,222	1.06%

Estimated EV Energy with Projected EIA Sales

EIA AEO 2018 Projection



2X EIA AEO 2018 Projection



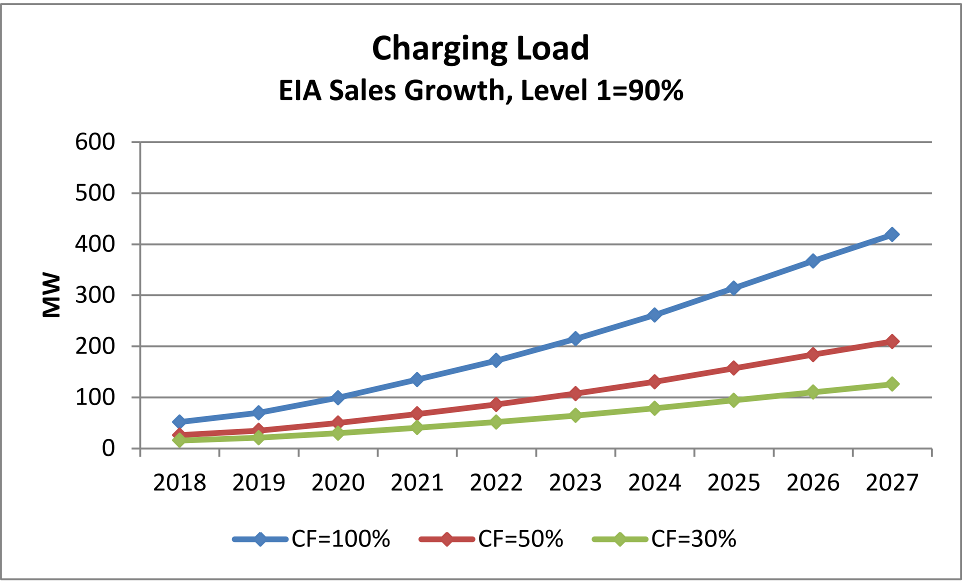
Estimated EV Summer Demand with Projected EIA Sales

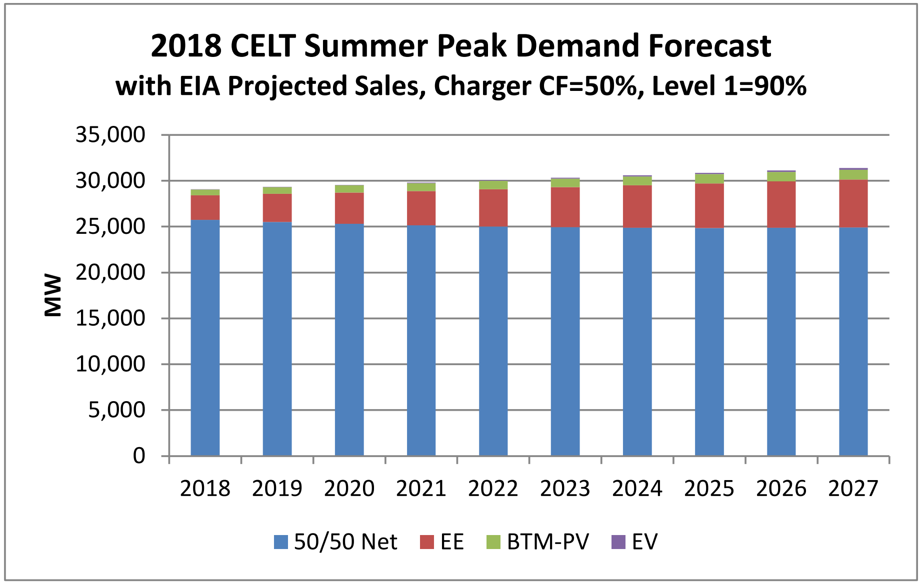
Charger ratio: Level 1=0.9, Level 2=0.1, CF =0.5

	2018 CELT (MW)				
	50/50 Net	EE	BTM-PV	EV	% of 50/50
2018	25,728	2,699	633	26	0.10%
2019	25,512	3,066	721	35	0.14%
2020	25,298	3,416	790	50	0.20%
2021	25,136	3,757	851	67	0.27%
2022	25,021	4,072	901	86	0.34%
2023	24,942	4,359	945	107	0.43%
2024	24,889	4,617	980	131	0.52%
2025	24,864	4,848	1009	157	0.63%
2026	24,874	5,052	1031	183	0.74%
2027	24,912	5,229	1051	209	0.84%

Estimated EV Summer Demand with Projected EIA Sales

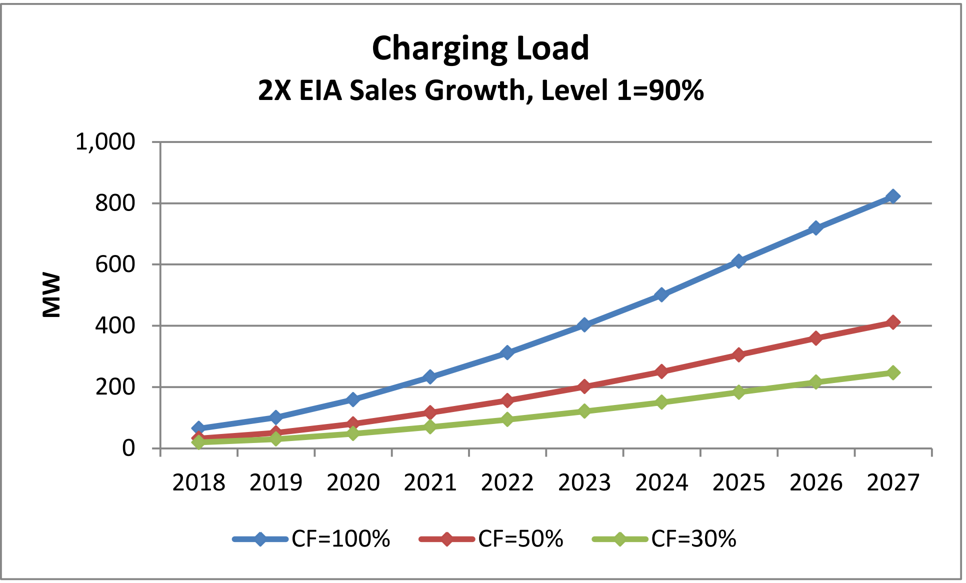
Charger ratio: Level 1=0.9, Level 2=0.1

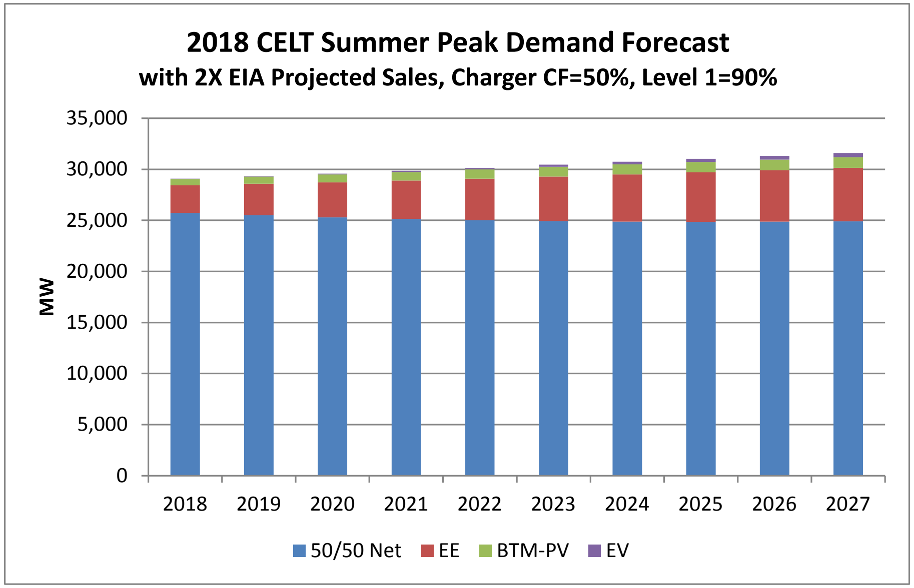




Estimated EV Summer Demand with 2X Projected EIA Sales

Charger ratio: Level 1=0.9, Level 2=0.1, CF =0.5





MONTHLY ENERGY MODELING

Energy Reconstitution Review

Explanation of Gross and Net Load Forecasts

- The ISO annually develops 10-year forecasts of energy and demand that are published as part of the Capacity, Energy, Loads, and Transmission (CELT) report
- ISO first develops "gross" load forecasts that reflect a forecast of load without reductions from passive demand resources, also called Energy Efficiency (EE) resources and behind-the-meter PV (BTM PV)
  - EE and BTM PV are reconstituted into historical hourly loads used to estimate gross load forecast models
  - Reconstitution ensures proper accounting of EE and BTM PV, which are both forecast separately
  - Reconstitution also includes load reductions from active demand resources, also called price responsive demand resources (PRD)
- "Net" load forecasts are developed by subtracting EE and BTM PV from the gross forecasts
  - Historical net loads include reconstitution of load reductions from active demand resources only
  - Net loads are intended to be representative of energy and loads observed in New England in real-time

Proposed Energy Forecast Methodology

- Current Methodology (Annual models – 7 total)
  - Region and state models forecast annual energy out 10 years
  - Models are estimated using reconstituted annual (gross) energy from 1990-2017
  - Models incorporate Moody's macroeconomic forecast
  - The ISO assumes normal weather for the energy forecast, defined as the 20 year annual average of HDD and CDD from 1996-2015
  - All variables in logarithmic scale
- Proposed Methodology (Monthly models 7 X 12 = 84 total)
  - Region and state models forecast monthly energy out 10 years
  - Models are estimated using reconstituted monthly (gross) energy from 1990-2017
  - Models incorporate Moody's macroeconomic forecast
  - Same normal weather as above
  - Logarithmic scale is not used for variables

Benefits of Monthly Models

- HDD and CDD are focused on a monthly level of energy usage
  - Annual models consider some HDD and CDD that have little to no impact on annual energy usage
    - How do a few CDD in the cooling season influence annual energy usage?
    - How do a few HDD in the heating season influence annual energy usage?
    - Not all CDD or HDD are created equal, i.e. a CDD in May has a different impact than a CDD in July or August
  - In monthly models, CDD and HDD are directly tied to a specific month's energy

- Enables weather normalization of energy at the state level
  - The deviation between actual degree days (DD) and normal DD multiplied by the DD coefficients adjusts the actual energy to a 'normal' level
    - $\text{Weather Adjustment}_t = (\text{Normal DD}_t - \text{Actual DD}_t) * ß_t(\text{DD})$

- 'What if' analysis
  - What if January and February both reach the 90^{th} percentile of HDD?
  - Scenarios can be easily constructed using the monthly distribution of HDD/CDD depending on the month

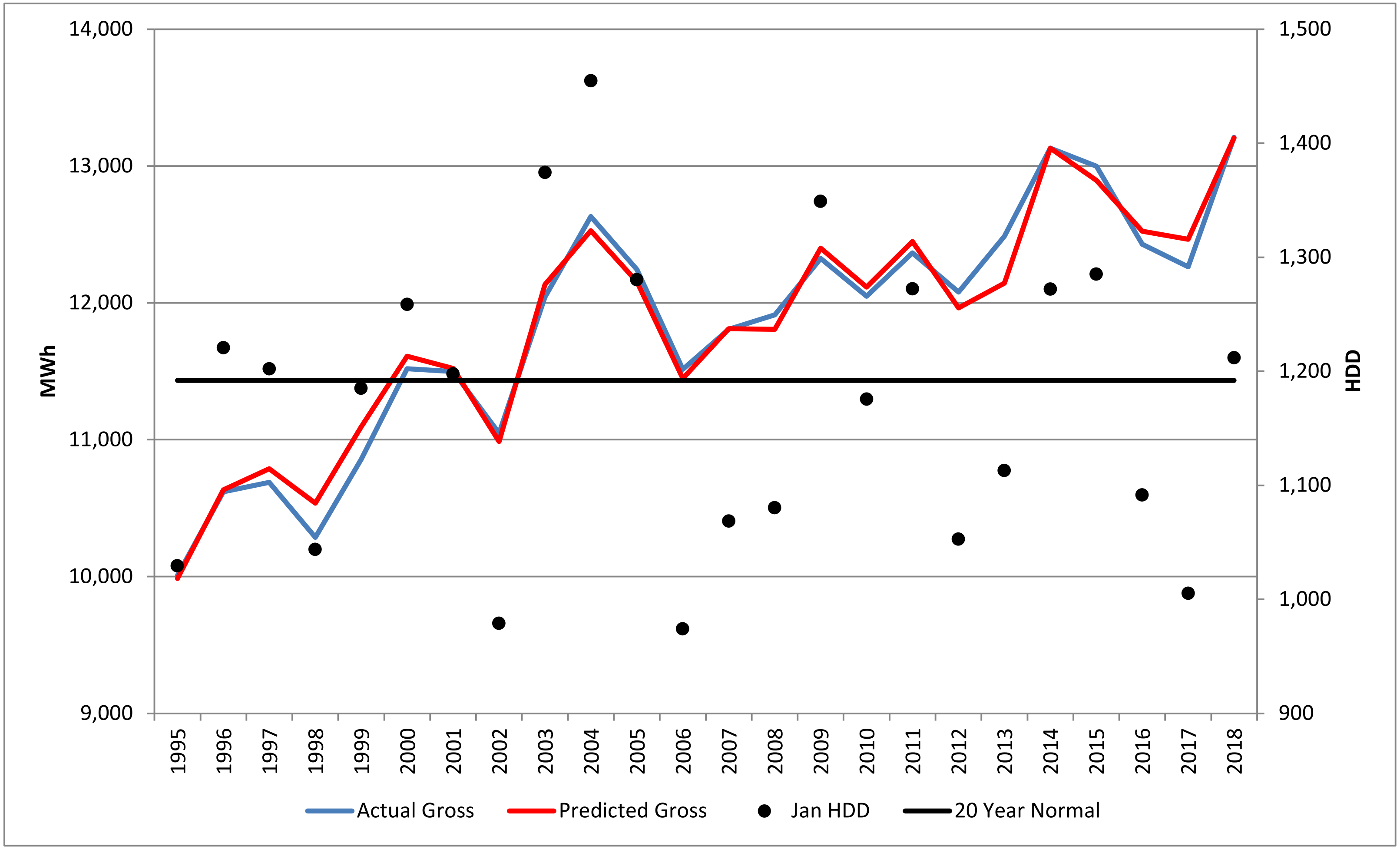
Regional Monthly Model Coefficients and Fit

- Highlights
  - CDD used in months May thru October
  - HDD used in months November thru April
  - Price of electricity significant in 'summer' months of Jul, Aug and Sep
  - Introduce a variable to account for heat pump penetration (ITRON SAE model)
  - R-square statistic is desirable
  - All t-statistics are significant
- Methodology and results are preliminary

		COEFFICIENTS					
	R-sq	Intercept	RGSP	HDD	CDD	Price	HP
Jan	0.981	3,466	6.659	2.634	0	0	146.3
Feb	0.988	2,565	5.941	3.138	0	0	170.0
Mar	0.972	3,830	6.051	2.625	0	0	118.1
Apr	0.980	4,465	5.899	1.338	0	0	36.8
May	0.989	4,638	6.750	0	22.110	0	0
Jun	0.986	3,879	8.194	0	12.882	0	0
Jul	0.983	2,787	10.696	0	13.651	-23.99	0
Aug	0.986	3,112	10.239	0	13.298	-12.94	0
Sep	0.980	5,235	7.516	0	12.273	-66.18	0
Oct	0.987	5,327	6.257	0	28.990	0	0
Nov	0.986	4,387	5.988	1.797	0	0	0
Dec	0.986	3,964	6.855	2.211	0	0	96.5

Regional January Energy Model

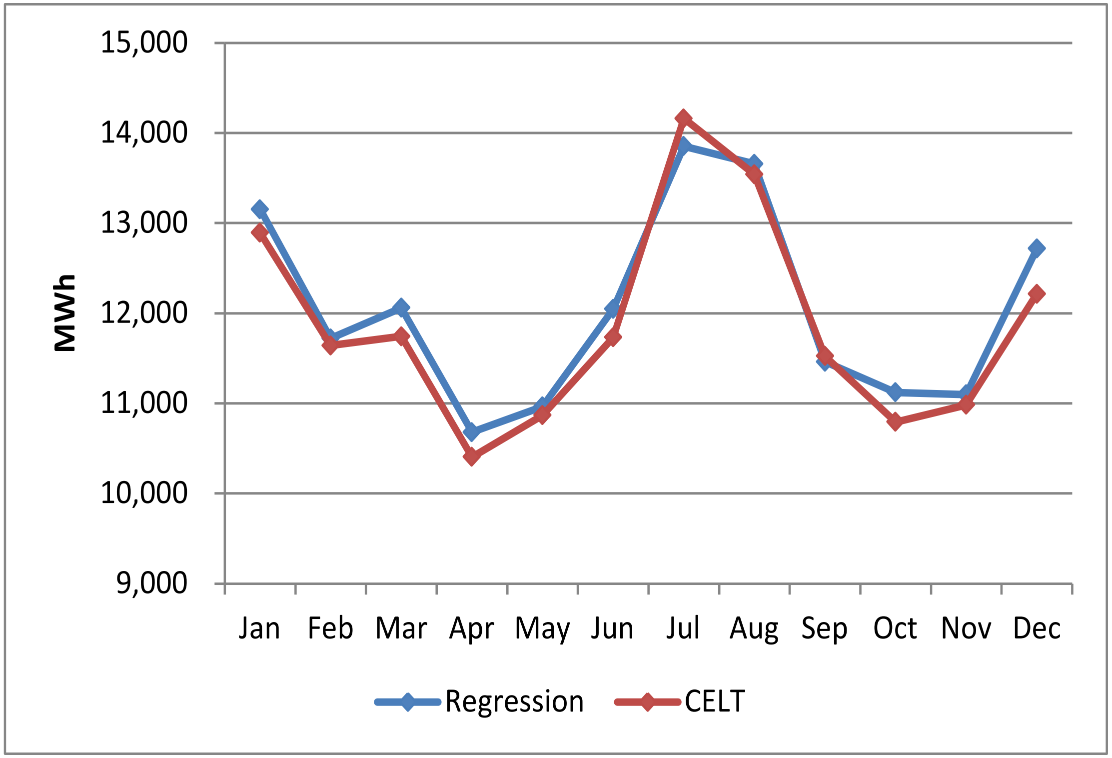
Actual vs Predicted with Monthly HDDs



2018 Regional Energy Forecast Comparison

Monthly Models vs Monthly Proportions*

	2018 Regional Energy Forecast		
	Regression	CELT	% Change
Jan	13,153	12,892	2.0%
Feb	11,720	11,641	0.7%
Mar	12,058	11,742	2.7%
Apr	10,679	10,404	2.6%
May	10,964	10,866	0.9%
Jun	12,046	11,732	2.7%
Jul	13,852	14,159	-2.2%
Aug	13,657	13,541	0.9%
Sep	11,462	11,522	-0.5%
Oct	11,122	10,793	3.0%
Nov	11,098	10,982	1.1%
Dec	12,715	12,214	4.1%
Annual	144,524	142,488	1.4%



* Monthly model estimates are preliminary

Weather Normalization Example

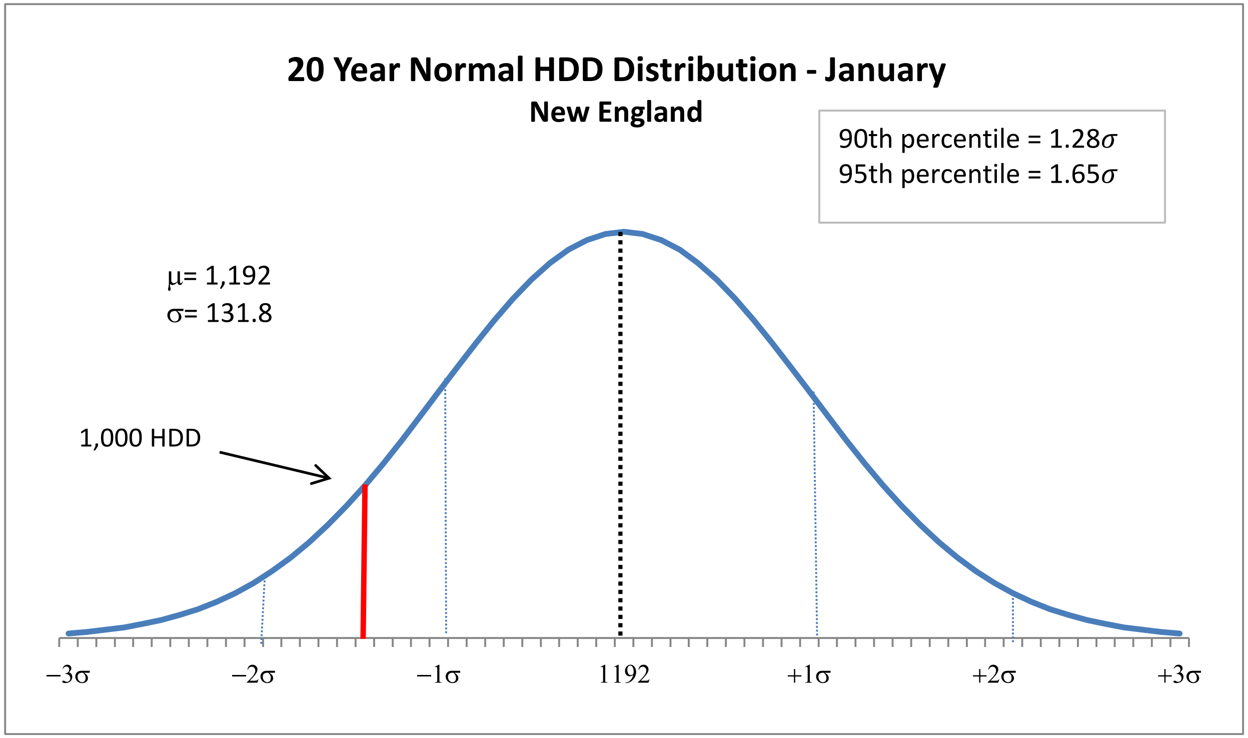
What would the energy in January have been under normal weather?

Actual January MWh = 12,600 MWh; Actual January HDD = 1,000

Weather Normal = Actual MWh + ((Normal HDD - Actual HDD) * β(HDD))

= 12,600 + ((1,192 – 1,000) * 2.634)

= 12,600 + 506 = 13,106 MWh



Scenario: January 95th Percentile Weather

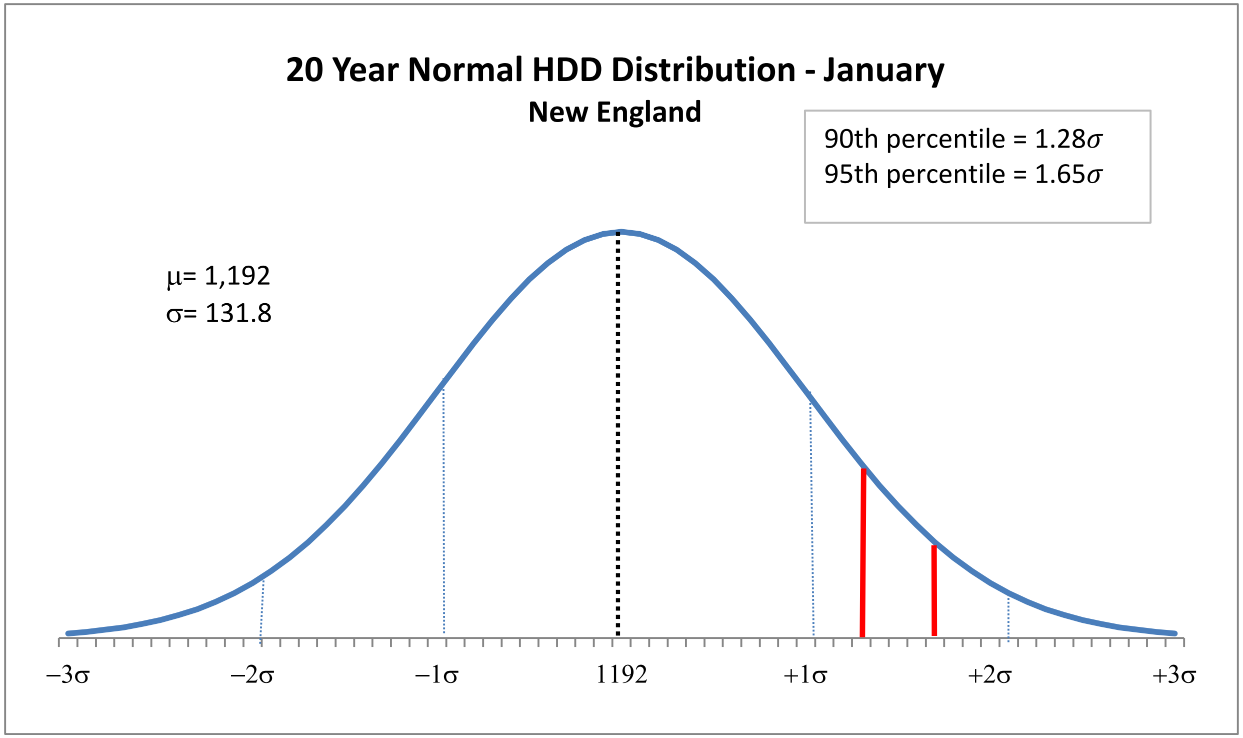
What is the energy impact if January weather approaches the 95 percentile of HDD?

Additional GWh = (P95 – μ) * β(HDD)

where P95 = μ +(1.65 * σ)

= 1,192 + (1.65 * 131.8) = 1,409.5 Degree Days

= (1409.5 – 1192) * 2.634 = 573 GWh of additional energy



Conclusions

- The New England states are promoting GHG reductions on a state-by-state basis, and at the regional level, through a combination of legislative mandates and aspirational, non-binding goals
- Early signs of “strategic” or “beneficial” electrification are beginning to emerge in New England, but their aggregate impacts on load are not yet significant
- If extensive electrification of the transportation and heating sectors were to occur, a significant amount of electric energy would be introduced to the region’s grid
- ISO is actively working to better understand the overall landscape and anticipated outlook for these emerging electric end uses, and especially that of EVs and ASHPs
- The anticipated rate of EV adoption in the near-term (0-5 years) does not appear likely to cause significant energy or demand growth
- Large-scale electrification will likely become a more significant consideration within the longer term outlook, and especially beyond the 10-year forecast horizon

Next Steps

- The 2019 forecast cycle has begun
- Tentative LFC meeting dates for the 2019 forecast cycle are as follows:
  - December 14, 2018
  - February 2019 (date TBD)
  - March 2019 (date TBD)
- ISO will continue working on the monthly energy forecasting discussed for implementation as part of the 2019 forecast
- ISO will continue monitoring the previously described emerging issues, and share and discuss findings with the LFC as appropriate
- The ISO welcomes LFC stakeholder feedback

Questions